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Problem-Based Learning in Improving Student Learning Outcomes in Biology Learning

Amirra Putri[1], Soesy Asiah Soesilawati[1], Neneng Diani[2]
[1]Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
[2]SMAN 17 Bandung, Bandung, Indonesia

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ABSTRACT

This study explores the impact of the Problem-Based Learning (PBL) method on improving biology learning outcomes among high school students. Despite biology's critical role in addressing global challenges, students often struggle with understanding basic biological concepts, leading to unsatisfactory academic performance. This research aimed to assess the effectiveness of PBL in enhancing students' biology comprehension. The study was conducted at SMAN 17 Bandung with 69 students as participants and utilized a one-group pretest-posttest design. Data were collected through a validated learning outcome test and analyzed using a paired sample t-test. The results indicated a significant improvement in students' post-test scores, with a mean difference of 38.88 points between the pretest and post-test and an N-gain of 0.703, categorized as high. These findings demonstrate that PBL significantly enhances students' understanding of biology by encouraging active engagement, critical thinking, and problem-solving. The study concludes that PBL is an effective learning method that improves biology learning outcomes, preparing students to become independent and collaborative problem solvers. However, challenges such as teacher readiness, time constraints, and limited resources must be addressed for broader implementation.

Corresponding Author:

Soesy Asiah Soesilawati
Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia
Jl. Dr. Setiabudi No.229, Bandung, Indonesia
Email: shanoonrebves@yahoo.com

1. INTRODUCTION

The development of education largely determines the progress of a nation [1]. Advanced education will have a positive impact on the welfare of society and vice versa. With a sound education system, a country can create the next generation that is superior and highly competitive globally. Education is vital in developing a country [2], [3]. Biology is one of the fields of science that significantly contributes to education. Biology teaches us about life, from the cellular level to the ecosystem, and has broad implications in various sectors such as health, agriculture, and the environment. Biological knowledge is crucial in overcoming various global challenges today, such as the health crisis due to infectious diseases, food security issues, and the impact of climate change. Therefore, applying a good mastery of biology concepts can help a country create a more prosperous and sustainable society.

Although biology has an important role, the reality in the field shows that students' biology learning outcomes are still relatively low. Many students have difficulty understanding the basic concepts of biology [4]–[8], so their academic performance in this subject is unsatisfactory. Based on various evaluations and studies, students' biology learning achievements in various countries, including Indonesia, still do not reach the expected standards. This is a severe problem for the education system because students' low understanding of biology

will hinder their mastery of other related sciences and reduce their readiness to face challenges in work and everyday life.

One of the main factors that cause low biology learning outcomes is the learning methods that tend to be passive [9]–[12]. Most teachers still use conventional approaches [13], such as one-way lectures, that make students less actively involved in the learning process. In addition, the limitations of adequate laboratory facilities are also an obstacle in learning biology. Learning that should be based on practice and experimentation is often only done theoretically, so students do not get a concrete learning experience. Other factors include low student interest in biology [14], lack of innovation in learning media [15], and a curriculum that is too dense with material but lacks contextual applications in real life [16].

One solution that can be implemented to overcome this problem is applying the Problem-Based Learning (PBL) learning method. PBL is a learning approach that emphasizes real problem-solving as the center of the learning process [17], [18]. In PBL, students are not only passively receiving information but are encouraged to actively seek solutions to the problems given. This involves various critical thinking skills, analysis, and collaboration between students in teams. The virtue of PBL is its ability to increase students' active involvement and encourage them to think creatively and independently. In addition, PBL helps students link the theory learned with real-life situations to more easily understand biological concepts and increase learning motivation. Thus, applying PBL is expected to improve students' biology learning outcomes and prepare them to become reliable problem solvers.

2. METHOD

This quantitative study aims to measure the effect of learning methods on student learning outcomes after implementing PBL in Biology learning. Quantitative research is focused on uncovering phenomena based on numerical data. Quantitative research in education focuses on collecting and analyzing numerical data to identify patterns or cause-and-effect relationships between variables [19]. The research design used was a one-group pretest-posttest design [20], where measurements were taken before and after treatment in the same group. The virtue of this design is that it allows the researcher to evaluate the changes that occur in the subject after being given treatment to see the direct impact of the intervention carried out.

The subjects of this study were 69 students of class XI IPA in two classes. This research was conducted in SMAN 17 Bandung. The sample selection was done using a simple random sampling technique, where each student in the Population had the same opportunity to be selected as a research sample, resulting in a representative sample. The data collection instrument was a learning outcome test with 24 multiple-choice questions that had been tested for validity and reliability. These questions measured students' understanding of biological material before and after treatment.

The data obtained were analyzed using quantitative statistical analysis techniques. Data analysis was done by comparing pretest and posttest scores to see significant differences in learning outcomes before and after treatment. The statistical test used is the paired sample t-test, which tests whether a significant difference exists between the average pretest and posttest scores. If the test results show a significant difference, it can be concluded that the applied learning method positively impacts student learning outcomes. In addition, the n-gain value was calculated, and the results obtained were categorized according to Hake (1999) [21].

3. RESULTS AND DISCUSSION

3.1. The effect of Problem-Based Learning on biology learning outcomes

To see the effectiveness of PBL in improving Biology learning outcomes, we analyzed students' pretest-posttest scores by calculating descriptive statistics.

Table 1. Descriptive statistics of learning outcome data during pretest and posttest

Statistic	Pretest	Posttest
Min.	29.17	66.67
Max.	58.33	100.00
Mean	44.69	83.57
Standard Deviation	8.24	8.72
Skewness	0.07	0.04

Based on the descriptive data in Table 1 regarding student learning outcomes in the pretest and posttest, there is a significant increase in student learning outcomes after applying the Problem-Based Learning (PBL) method in learning Biology. At the pretest stage, the minimum student score was 29.17, while the maximum score was 58.33, with an average (mean) of 44.69. This average indicates that before the implementation of PBL, students' understanding of the topics was relatively low, which may reflect a lack of active engagement or deep understanding of the concepts being taught. After the implementation of PBL, the

post-test results showed a clear improvement. The minimum score increased to 66.67, while the maximum score reached 100.00. The average post-test score also increased significantly to 83.57. This increase shows that after implementing problem-based learning, students' ability to understand Biology material increased substantially. The difference between the pretest and posttest averages reaching 38.88 points shows that the PBL method significantly positively impacts student learning outcomes. Regarding standard deviation, the pretest data had a value of 8.24, while the posttest data was slightly higher at 8.72. This shows that the variation in scores among students tends to be stable, both before and after the implementation of PBL. However, the small increase in standard deviation in the posttest indicates that although most students experienced an increase in scores, there was little difference in the extent of the increase among students. The skewness of the data on the pretest (0.07) and posttest (0.04) showed that the data distribution tended to be symmetrical, both before and after the intervention. This means that students' learning outcomes were evenly distributed, with no over-concentration in low or high scores, both in the pretest and post-test.

These descriptive results show that implementing Problem-Based Learning significantly improved students' Biology learning outcomes. PBL, with its problem-solving-focused approach and active student engagement, proved to be effective in helping students understand more complex concepts and improve their academic achievement. This study provides evidence that PBL method can be adopted as an efficient learning strategy to improve the quality of Biology learning in schools.

Table 2. Results of pretest and post-test data normality test analysis

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
Pretest	0.107	69	0.054
Post-test	0.099	69	0.091

a. Lilliefors Significance Correction

Based on the normality test analysis using the Kolmogorov-Smirnov test with Lilliefors significance correction, the test results for the pretest and post-test data are shown in Table 2. This normality test aims to determine whether the pretest and posttest data are normally distributed, which is one of the important assumptions before conducting further statistical analysis, especially parametric analysis such as the t-test. For pretest data, the Kolmogorov-Smirnov statistical value is 0.107 with a significance value (Sig.) of 0.054. Since the significance value is greater than the critical limit of 0.05, it can be concluded that the pretest data is normally distributed. This indicates no significant deviation from the normal distribution for the pretest data. Meanwhile, the Kolmogorov-Smirnov statistical value for post-test data is 0.099, with a significance value of 0.091. Like the pretest, a significance value greater than 0.05 indicates that the posttest data is also normally distributed. With these two normality test results, it can be concluded that both pretest and posttest data fulfill the assumption of normal distribution. Thus, the t-test results that have been carried out are valid and can be interpreted further without violating the normality assumption.

Table 4. Paired samples t-test analysis result

		Paired Differences					t	f	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest - Posttest	-38.889	6.0495	0.728	-40.343	-37.436	-53.399	8	0.000

Based on Table 4, the results of the paired sample t-test conducted to compare pretest and posttest scores showed a mean difference of -38.889. This indicates that, on average, there was a significant increase in scores on the post-test compared to the pretest, with the mean post-test score being higher by approximately 38.889 points. The standard deviation value of 6.0495 shows that the variation between students in the difference between pretest and posttest scores is relatively small, indicating that the improvement in Learning outcomes was fairly consistent across the student sample. The standard error of the mean of 0.728 also indicates that the estimate of the mean difference is relatively accurate.

The 95% confidence interval is between -40.343 and -37.436. This means that we can be confident with a 95% confidence level that the true mean difference between the pretest and posttest scores falls within that range, and the negative value indicates that the posttest scores are consistently higher than the pretest. The t-value of -53.399 with a degree of freedom (df) of 8 indicates that the observed difference is highly statistically significant. With a Sig. (2-tailed) or p-value of 0.000, which is much smaller than 0.05, it can be concluded that the difference between pretest and posttest scores is significant. That is, there is a real improvement after the treatment or intervention given.

Based on the study's results, the N-gain obtained was 0.703, included in the high category. N-gain is an indicator used to measure the effectiveness of a learning method in improving student understanding, with values ranging from 0 to 1. The N-gain value of 0.703 indicates that PBL significantly improves student learning outcomes. This high N-gain value indicates that after participating in learning with the PBL method, most students experienced a substantial increase in understanding of Biology material. PBL encourages students to actively seek solutions to the problems given so that they memorize biological concepts and understand their application in real life. This approach allows students to engage in a more in-depth and meaningful learning process, ultimately improving their learning outcomes.

In addition, PBL also provides opportunities for students to develop critical thinking skills [22], [23], solve problems [24], and work together in groups. These skills are very important in learning Biology, which often requires analysis of complex natural phenomena and interconnections between various concepts. With PBL, students can better internalize the material and improve their overall understanding, reflected in the increased post-test scores and high N-gain. With an N-gain value of 0.703, it is clear that PBL improves students' academic scores and helps them build a strong foundation in understanding biology concepts. This confirms that PBL is an effective method for creating learning that is more interactive, collaborative, and relevant to the real world so that it can produce significant improvements in student learning outcomes.

PBL has been proven to be an effective learning method in improving Biology learning outcomes, mainly because it centers learning on students and encourages their active involvement in the learning process [25], [26]. With PBL, we find students are more active in learning and more enthusiastic in following the learning process. One of the main benefits of PBL in improving learning outcomes is its ability to develop critical thinking skills. In PBL, students are faced with real problems relevant to their daily lives, and they are required to analyze, evaluate, and find solutions to these problems. This problem-solving process allows students to develop deeper analytical thinking skills, improving their understanding of more complex Biology concepts. With PBL, students are trained to understand the problem and plan the solution to communicate the results of their work.

In addition, PBL encourages students to learn independently and work in groups, which increases learning motivation and collaborative skills. Students are trained to find the necessary information, build knowledge from various sources, and then discuss it with their peers. This process helps them not only master the material but also understand how the concepts are interconnected and applied in a real context. Collaboration in PBL allows the exchange of ideas, enriches insights, and builds a deeper understanding, which is crucial in learning Biology.

Another benefit of PBL is that it improves knowledge retention. By involving students in an interactive and problem-based learning process, PBL makes learning more meaningful and contextual, making the material learned easier to remember and apply. This can help students to store the knowledge they have just learned in their long-term memory and can help students link the materials they have learned with the newly acquired materials. PBL also trains students to develop metacognitive skills [27]–[30], which is the ability to plan, monitor, and evaluate their learning process. These skills enable students to become more independent and effective learners, which not only helps in exams but also in long-term learning.

In addition, PBL allows for directly applying Biology concepts to real-world scenarios. This is especially important in a subject like Biology, which has much to do with natural phenomena and everyday life. Students can see the direct relevance of what they are learning, for example, in understanding ecosystems, genetics, or physiological processes, so they are more encouraged to be actively involved in learning. Thus, PBL is not only effective in improving Biology learning outcomes, but also in shaping students into individuals who can think critically, work collaboratively, and apply their knowledge in real situations. These benefits make PBL a suitable approach to be applied in Biology education, especially in facing the challenges of the 21st century that demand higher-order thinking skills and adaptability in various contexts.

3.2. Challenges of implementing Problem-Based Learning in Biology learning

Applying Problem-Based Learning (PBL) in school learning offers many benefits, especially in increasing students' active involvement, critical thinking skills, and problem-solving skills. However, implementing PBL also faces various challenges that must be considered [31], [32]. One of the main challenges is the readiness of teachers to implement this method effectively [33]. PBL requires teachers who not only master the material but are also able to facilitate an exploratory and collaborative learning process. Teachers must be able to guide students in problem-solving without providing solutions directly, which is a pedagogical skill that all teachers do not always possess.

Another challenge is the time required to implement PBL [34], [35]. This method requires more time than traditional learning methods, as students have to identify problems, explore information, have group discussions, and find solutions. In a crowded curriculum, allocating enough time for PBL can be

an obstacle. Time is a constraint for delivering dense learning topics but limited time allocation [36]. Limited facilities and resources can also be an obstacle, especially in schools that do not have adequate access to technology or references needed to support students' exploration process. This study also found a lack of facilities that support learning. Students need sufficient resources such as books, internet access, and teaching aids to conduct comprehensive research and problem-solving.

Students' motivation and ability are also important factors in successfully implementing PBL [37]. Not all students have the high motivation or critical thinking skills necessary to participate effectively in PBL. Some students may find it difficult when faced with learning situations that demand greater independence and initiative than conventional learning methods. This may lead to a gap between students who can adapt to PBL and students who require more intensive guidance.

Future research must consider several things to overcome this challenge. First, teachers must be trained to ensure they have the skills to implement PBL. Teachers need to be briefed on facilitation techniques, classroom management, and how to design problem scenarios that are relevant and interesting to students. Second, future research needs to focus on a more flexible curriculum design to integrate PBL methods without disrupting the time allocation for other subjects. One solution could be a more relaxed schedule or reduced memorized content.

In addition, future research should focus on developing support strategies for students who have difficulty following PBL, such as additional guidance or material enrichment. The use of technology, such as interactive online learning platforms, could also be one solution to provide easier access to information for students, especially those with limited resources at school. Thus, future research should explore various supporting aspects so that PBL can be implemented effectively and equitably in various types of schools and can improve student learning outcomes as a whole.

4. CONCLUSION

Based on the study results, the application of Problem-Based Learning (PBL) proved effective in improving students' Biology learning outcomes. Descriptive statistical analysis showed a significant increase in posttest scores compared to the pretest. The average student score increased from 44.69 on the pretest to 83.57 on the posttest, with an average difference of 38.88 points. This increase indicates that PBL succeeded in encouraging students' understanding of Biology material more deeply and comprehensively. In addition, the normality test results confirmed that the pretest and posttest data were normally distributed, which allowed further statistical analysis with the paired t-test. The t-test showed statistically significant results, with a p-value of 0.000, confirming that a marked improvement in student learning outcomes occurred after implementing PBL.

Although PBL offers many benefits, this study also identified some challenges in its implementation, such as teacher readiness, longer time allocation, limited resources, and variations in student motivation and ability. Future research needs to focus on developing teacher training, a more flexible curriculum, and additional support for students who struggle with PBL. With these strategies, PBL can be applied more effectively and thoroughly to improve the quality of Biology learning in various school contexts.

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